

BASIC MAGNESIAN ROCKS
ASSOCIATED WITH THE
CORUNDUM DEPOSITS OF GEORGIA

A DISSERTATION
SUBMITTED TO THE BOARD OF UNIVERSITY STUDIES
OF THE JOHNS HOPKINS UNIVERSITY IN PARTIAL
FULFILMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY

BY
FRANCIS PLAISTED KING
1897

BALTIMORE, MD.
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INTRODUCTION.¹

Since the discovery of corundum in North Carolina and Georgia some quarter of a century ago, the economic importance of the material has attracted the attention of many investigators to the deposits of these two states, the majority interested in its genetic relations that prospecting might be assisted, and a very few in its scientific study. To the former, nevertheless, the latter are much indebted since their exertions stimulated the extensive explorations which have made possible much of the work of the scientist. The results of their labors are to be found in a literature not voluminous, but quite diversified in range of subject matter; publications in which the authors have abstained generally from more than a simple setting forth of field observations and laboratory experiments.² The literature includes papers on the genesis, paragenesis, and alteration products of corundum; also papers concerning the corundum-bearing formations and their field relations. Some are solely descriptive, others contain brief suggestions and arguments for the solution of the various mineralogical and geological problems presented. In these writings, the type rocks of the corundum-bearing formations have been discussed under group or field names, and with one exception³ the authors have made little attempt to distinguish or specifically describe them. Indeed, the trend of work has been economical and mineralogical rather than petrographical; therefore, on account of the number of types and type facies found in the corundum-bearing formations of Georgia, and the interesting features which the microscope has revealed in some, the writer has been advised to present the results of their petrographical study.

In the laboratory investigations of these rocks, the writer has been assisted by Professors Rosenbusch and A. Osaan of Heidelberg, Germany, and Dr. Mathews of Johns Hopkins University, to which gentlemen he here takes pleasure in acknowledging their guidance and help.

¹The author has not had the opportunity of revising the proof of this article.

²See Bull. 2, Geol. Survey, Ga., 1894, pp. 176-178. Bull. 11, Geol. Survey, N. C., 1896, pp. 99-101.

³Bull. 11, Geol. Survey, N. C., by Joseph Volney Lewis, 1896.

GEOLOGICAL RELATIONS AND OCCURRENCES.

The corundum-bearing basic magnesian rocks of Georgia occur as intrusive lenticular masses in a well-defined gneissic zone of the Crystalline Area, a region co-extensive with the great Appalachian mountain system and occupying almost the entire northern portion of the state. This Crystalline Area embraces a surface area of about 13,000 square miles: It extends south to a line drawn east from Columbus, through Macon, to Augusta, below which the crystalline rocks disappear beneath the Mesozoic and Cenozoic elastics; to the northwest its boundary is marked by a gigantic physical break, the Cartersville Fault, which distinctly separates it from the fauna-bearing Paleozoic sediments which sweep across the northwest corner of Georgia.

The topography presents the configuration produced by natural processes, changes brought about by constructive and destructive forces. Atmospheric and aqueous agencies which have been actively at work in this region since the great earth-movements, following the coal epoch which uplifted the Appalachian system, have removed thousands of feet of the various formations, and sculptured the area into its present landscape. Hence this crystalline region presents a more or less diversified topography. The southern portion of the area is broken by undulating hills, intensified along the large rivers. These elevations increase as the foot-hills of the Blue Ridge are approached, their regularity only in rare instances interrupted now and then by monadnocks of granite which rise more or less abruptly as bold and rugged features of the landscape. Stone Mountain, twelve miles east of Atlanta, the most striking example of such a monadnock, rises precipitously a quite bare mass of granite nearly 800 feet above the surrounding country—finally the Blue Ridge itself, peaks of which in Georgia range from 3000 to 4000 feet above sea level, the highest, Mt. Enotah, attaining an elevation of 4790 feet. The drainage is that common to all mountainous districts and areas approaching sea-level. Tributaries of the Tennessee river drain the northern part of the Crystalline Area, while the southern is drained by the Savannah, Ogeechee, Oconee, Ocmulgee, Flint, and Chattahoochee rivers. Where the crystalline rocks are flanked by the soft elastics on the south, their line of demarkation is indicated by the topography and stream-bed features; to the north and west, where flanked by the Paleozoics, *i. e.* at the Cartersville Fault, this line is most prominently defined. "In consequence of the induration of the rocks east of the Fault, its

position is clearly indicated by the topography. The metamorphic rocks form a nearly continuous line of bluffs from one to three hundred feet higher than adjacent portions of the valley. These bluffs are the western escarpment of extensive ancient base-levels through which the streams flow in deeply eroded channels.”⁴

Geologists who have worked in the Southern Appalachians, have extended their labor little beyond the eastern confines of the fauna-bearing clastics, hence with the exception of the metamorphic zone bordering the known Paleozoic sediments, the remaining crystalline region, on account of the crystalline character of its rocks and complex structure, has long been considered a remnant portion of the continental nucleus and the applied age Archaean has ever remained generally accepted and unquestioned. In recent years, however, the rapid strides in geologic science have thrown so much light on formations similar to those presented in this region as to question seriously any such embracive correlation. Indeed, moved by new facts, the swing of the pendulum of scientific opinion is to the point expressed by Keith in an unpublished paper before the Geological Society of Washington, wherein he stated that the Atlantic Crystalline Area is probably in large part a continuation of the Appalachian palaeozoics.

Our present knowledge of the Georgia Crystalline Area permits a rough division of the region into four zones: First, a narrow belt of semi-metamorphic rocks which arch around the fauna-bearing clastics of the Paleozoic, from which they are separated by the Cartersville Fault. Second, a broad belt of crystalline rocks through which are intruded the basic magnesian rocks carrying corundum. Third, another belt of semi-metamorphic rocks much narrower than the first. Fourth, an extensive belt of crystalline rocks which occupy the remaining portion of the Crystalline Area.

The first zone comprises the Ocoee group of Safford, which Hayes⁵ describes as varying in width from one to twelve miles and differing widely in degree of its metamorphism. It is composed in great part of semi-metamorphic hydromica schist, slates, conglomerates, sandstone, and quartzite. “As to the age of the Ocoee group, there has been little, if any, evidence discovered in the area represented in the accompanying

⁴“The Overthrust Faults of the Southern Appalachians.” C. Willard Hayes, *Bull. Geol. Soc. Amer.*, vol. ii, 1891, p. 147.

⁵*Bull. Geol. Soc. Amer.*, vol. ii, 1891, pp. 148, 149.

map.⁶ The rocks have as yet yielded no fossils, and they are separated by a fault of unknown displacement from rocks whose age can be determined by palaeontological evidence. The work of Willis and Keith in east Tennessee, however, has firmly established the position of a corresponding group in the Big Butt range and east of Chilhowee mountain as belonging to the upper Silurian, and the rocks are continuous from one region to the other."⁷

The third zone probably represents a southern extension of the North Carolina⁸ Eastern Ocoee belt. No detail work has been done on this zone in Georgia, and little is known regarding it. A mineral map of Georgia, compiled from state geological records and manuscript notes by the Department of Agriculture in 1885, shows a belt of marble entering Habersham county from South Carolina and passing through Clarksville, and Gainesville, and thence on toward Atlanta. This so-called marble was found to be a semi-crystalline blue limestone. Probably in the same series, the feldspathic quartzite through which the Tallulah river cuts its deep gorge and the supposed diamond-bearing itacolumnite of Gainesville may be associated. If it be true that this is a continuation of the eastern Ocoee of North Carolina, and the further extension of this be represented as continuing on to the Alabama line, then the Corundum Belt of North Carolina extends through Georgia under conditions identical with those described in North Carolina, since in the gneiss strip between these two semi-crystalline series are found, with one exception, all the corundum-bearing basic magnesian formations of Georgia.

The Corundum Belt represents the second zone, and to the east of the third lies the fourth zone. The fourth zone is likewise made up in great part of gneiss, but differs from the second in the presence of large areas of granite, and in an entire absence of corundum-bearing basic magnesian bodies, with the exception of a small, isolated line of outcroppings, 40 miles east of Atlanta. The structure of the Corundum Belt is that consequent upon great and continued earth movements. The sharp folds and faults which must exist in such a folded area are no longer noticeable. For instance, diorite has taken on a gneissoid structure, phyllites take the place of soft slates, and the basic magnesian rocks have been more or

⁶ Georgia and a portion of Tennessee and Alabama.

⁷ "The Overthrust Faults of the Southern Appalachians," by C. Willard Hayes, *Bull. Geol. Soc. Amer.*, vol. ii, 1891, p. 149.

⁸ See Geological Map of North Carolina.

less altered, as will be shown more fully in succeeding pages. Even local metamorphism, consequent upon igneous intrusion, is little, if at all, apparent in these gneisses. If these gneisses represent bedded sediments, as laboratory research is developing in the case of many of the gneisses along the Atlantic border, then the bedding planes have been effaced by excessive squeezing and cleavage planes substituted. The apparent constancy of strike north 30° east throughout the whole Crystalline Area, is one of the most interesting structural features. It shows almost conclusively that the entire area has been affected by great orographic movements, the objective point of which force was to the northwest, or at right angles to the present strike as determined by the cleavage. There can be little doubt, also, from the rocks and structural features of the Crystalline Area as a whole, that this force exerted itself over a long period of time. The Corundum Belt is evidently of greater age than the semi-metamorphic Ocoee series, and undoubtedly represents an axis of weakness in the continental uplifting prior to the deposition of the Ocoee, while a portion of the rents thus produced and filled with the igneous matter welling up from below now form the corundum-bearing basic magnesian bodies.

The Corundum Belt is broadest near the North Carolina line, having a width of about forty miles, narrows toward the center and broadens again as it approaches Alabama. The corundum-bearing basic magnesian formations are most numerous near North Carolina and occur only in isolated areas throughout the remaining portion of the belt. None of the formations are large, as the largest, that at Laurel Creek, Rabun county, only covers a few acres, and compared with this the majority are much smaller, or so obscured by subaerial decay and soil cultivation as to appear so. Their presence is usually indicated by the barrenness of the soil, and, where dunite is prominently developed, by a rusty ochre color. Indeed, these physical features—and especially the former—are almost invariably nature's stamp for formations of this character. They generally intrude the gneiss as irregularly elongated individual bodies, whose longer axes correspond to the strike of the country rock. Again they spin in a narrow strip like a string of beads for the distance of a mile or more. Although the Georgia map^o shows lines of these outcroppings, widely broken, a careful mapping of all formations similar in

^o Bull. 2, Geol. Survey, Georgia, 1894.

lithological character irrespective of the corundum content would reveal parallel lines of these bodies reaching across the state in a much less interrupted continuity.

DESCRIPTION OF THE BASIC MAGNESIAN ROCKS OF THE
GEORGIA CORUNDUM BELT.

On account of the intimate relations of the igneous rocks found in the corundum-bearing masses in Georgia, the writer has considered them under the general head: Basic Magnesian Rocks. The rock facies, however, will be grouped under the two following types:

1. The *Non-feldspathic*, or *Magnesian type*. This is the most extensive of the two. It embraces *dunite*, *harzburgite*, *epi-amphibole-picrite*, *anthophyllite-peridotite*, and *epi-amphibolite*, and includes serpentines associated with *hornblende*, *steatitic*, and *chloritic* masses which have been derived from them.

2. The *Plagioclase* or *Gabbro type*. This is closely related to the former type and includes *epi-diorite* and *olivine-gabbro*. The former is usually characterized by the presence of corundum. Both are especially marked by the effects of dynamic metamorphism, which is exhibited both in their structure and mineral composition.

Joseph Volney Lewis, formerly assistant State Geologist of North Carolina, in an admirable economic report on the "Corundum and the Basic Magnesian Rocks of Western North Carolina,"¹⁰ classified the basic magnesian rocks under the three groups: *peridotite*, *pyroxenites*, and *amphibolites*. This classification is used merely for a brief general description in which microscopical features are omitted. Since many of the rocks included in the following descriptions have been metamorphosed till their present mineralogical composition is quite different from that formed as a result of consolidation from a molten magma, the terms employed in this paper seem to the writer better adapted to petrographical usage.

The basic magnesian rocks of Georgia are identical with those of North Carolina, although as yet the large series found in North Carolina has not been fully duplicated in Georgia. It will be noticed, therefore, that some rocks mentioned by Lewis are not included in the following descriptions.

¹⁰ Bull. 2, Geol. Survey, N. C., 1896.

1. THE NON-FELDSPATHIC OR MAGNESIAN TYPE.

a. Dunite.

Specimens of dunite from which sections were cut were obtained from Laurel Creek and Miller's asbestos property, Rabun County, and Hog Creek, Towns County. In each instance, the dunite represents a differentiation of the mother liquor, and is the predominant phase. The splitting up of the molten magma, however, was not the same in each locality. In the first two occurrences, only the magnesian type was produced, while both the magnesian and the gabbro types were formed in the third.

The dunite at Laurel Creek is associated with anthophyllite rock. This "anthophyllite," however, forms but a small proportion of the intrusive body and its development is intricately intermingled with the dunite. A similar breaking up of the peridotite magma has been noted by Lewis in the similar basic masses of North Carolina where, as at Corundum Hill, Macon County, and in the Sapphire mining tract of Jackson County, "the anthophyllite rock forms a mass perfectly continuous with the dunite."¹¹

The dunite mass at Hog Creek forms the southwestern continuation of the peridotite body, and is distinct from that of the gabbro type in which occur the veins of corundum. Its distinguishing features are the presence of chromic-iron ore bodies, the nickel-gymnite, *genthite*, incrusting seams in the dunite, and its coarser texture.

At Miller's asbestos property, the dunite is found associated with epi-amphibole-picrite. Contact between these two members is concealed by vegetation. The dunite of this locality possesses a laminated structure not found in the others.

The structure of the Georgia dunite is that of a fine-grained granular rock—the grains of the Hog Creek dunite attaining the size of coarsely granulated sugar. Sometimes a pseudo-porphyrific phase occurs, due to development of anhedral phenocrysts of tremolite which frequently have the dimensions of an inch or a trifle more. Such development of tremolite in dunite is especially marked at Laurel Creek, where the usually massive rock is sometimes found more or less laminated. Under the microscope, sections cut transverse to the lamination show parallel bands

¹¹ Bull. 2, Geol. Survey, N. C., 1896, p. 26. Lewis described this as an "enstatite rock."

of coarse and fine olivine grains penetrated by needles of tremolite. The fine-grained bands consist of broken grains of olivine, the longer axis of which is parallel to the line of lamination. The coarser-grained bands also show the effects of crushing and the causes of this lamination is apparent.

The dunite fractures conchoidally and the freshly fractured surface possesses a yellowish-green color, with an oily resinous lustre. On weathering, the oil green color of a fresh surface changes to a light ochrous yellow. This rock is composed of a granular mass of olivine, with crystals and irregular grains of chromite, picotite, and magnetite. Besides these essential and characteristic constituents, tremolite, talc, chlorite, magnesite, and magnetite occur as accessories.

Olivine.—The olivine individuals are clear, colorless, and transparent. Cataclastic phenomena are always present—the olivine grains may be much broken and separated by fine cracks forming the “mörtel” structure, while other portions of the section show the large grains surrounded by the smaller. A less complete effect of dynamic action is shown frequently by the breaking of the large grains along more or less parallel lines, in which case the separation of the parts is only to be detected between crossed nicols. Inclusions of small opaque or reddish-brown octahedral, rounded, and irregular grains of chromite are quite common. Glass inclusions are also sometimes abundantly developed. The alteration into serpentine and tremolite is always more or less developed.

Spinellids.—The remaining essential constituents are the “spinellids,” a convenient term for magnetite, chromite, and picotite adopted by Fouquè and Lévy. The general opaqueness of these minerals renders any microscopical scheme of separation futile. As isomorphous mixtures, they have been shown¹² to grade insensibly into each other with the variations in the proportion of chromic acid present. Their occurrence is generally in rounded or irregular grains, but well defined octahedral outlines are not uncommon.

Tremolite.—The accessory constituent tremolite is present in all dunite sections, and most prominently in those from Laurel Creek. One hand specimen shows a fibrous aggregate two inches in length and one in breadth. Under the microscope the tremolite appears in plates, fibrous

¹² Renard, “Challenger,” vol. ii, Narrative, p. 10. Wadsworth, Mem. Comp. Zool., Harvard, vol. xi, p. 176.

aggregates, or most commonly in long fibrous needles, and is evidently a product of olivine alteration. In thin sections, the tremolite is colorless and transparent, and is further characterized by a high double refraction, transverse parting, and amphibole cleavage. The needles penetrate the cracks of the broken olivine grains in all directions. In a section from the Miller dunite, where shearing has produced irregularly parallel banded "mörtel" structure, the fibers are parallel to the line of shearing. Alteration of tremolite into talc occurs in various stages of development.

Serpentine.—The serpentine has a pale yellowish color, sometimes almost colorless. It follows the fissures of the olivine and fills the spaces intervening between the grains, and is plainly a product of their alteration. The optical character of the separate grains often shows that they belonged to one individual. The fibers of the serpentine stand at right angles to the walls of the fissures and show the common optical features.

Other constituents.—Dark green plates of chlorite are especially noticeable in the Laurel Creek dunite, where the plates often attain the dimensions of a half inch in the hand specimens. The optical properties of this chlorite suggest the variety clinochlore.

A colorless carbonate fills cavities in the dunite and is often so largely developed as to be seen in hand specimens. This was found to be unattacked by hydrochloric acid, and further testing by measurement of cleavage angle showed that it is the magnesian carbonate, *magnesite*.

Dunites in which the tremolite is altering to talc are spangled with the disseminated silvery flakes. Under the microscope the course of the alteration may be plainly followed. The progress of the alteration is along the peripheral borders and fissures and cleavage cracks of the individuals into which the talc scales have penetrated. Basal sections of tremolite in which the alteration is far advanced, show acutely rhombic meshes within a net of talc scales.

b. Harzburgite (Saxonite).

Specimens of this rock were taken from the so-called Soquee Corundum Mine in Habersham County, where a small prospector's cut furnished an opportunity to collect fresh material. The rock represents a transition phase of dunite in which the auxiliary constituent enstatite appears. Like the dunite at Laurel Creek, it is intermingled with the anthophyllite rock and accompanied by masses of serpentine and steatite as alteration products.

The rock possesses a porphyritic structure due to the presence of oil

green anhedral phenocrysts of enstatite. In unweathered specimens, the background is blue-black flecked with talc flakes and finely granular like the dunite. When weathered the harzburgite resembles the color of dunite so that after the alteration has progressed to the complete destruction of the original character of the enstatite the Georgia harzburgite cannot be distinguished from dunite even with the aid of the microscope.

Olivine forms the essential portion of the ground mass and is accompanied by grains of enstatite, chromite, picotite, and magnetite with the alteration minerals, serpentine, talc, magnesite, and chlorite.

Olivine.—The olivine is perfectly colorless and transparent presenting all the cataclastic phenomena observed in the dunite. Likewise, also, the surface is deeply shagreened and the interference colors high. It contains besides the inclusions of glass and spinellids observed in the olivine of the dunite, microscopic inclusions of apatite. Some grains are clouded with microscopic magnetite dust, this clouding advancing from the periphery inward. Alteration into serpentine has also developed between the grains and along the cracks, accompanied by the addition of magnetite dust which appears in fine concentric lines marking the progress of the alteration of the olivine. It is this extensive production of magnetite dust which has given the rock its present color.

Enstatite.—This mineral attains a size quite parallel to that of the tremolite of the Laurel Creek dunite. The large plates are often seen under the microscope to enclose grains of olivine in poecilitic structure. The enstatite is colorless in thin sections, and its pyroxene nature is shown by the crystal habit, low interference colors, pyroxene cleavage, and parallel extinction. Twins occur occasionally. Inclusions of small rounded grains of spinellids are present but not numerous. Alteration into talc is both partial and complete. This alteration may be observed along the cracks and periphery of the altering individual. Its advance is marked by a zone of talc needles standing at right angles to the cracks or outer edge of the individual.

Spinellids.—The spinellids of the harzburgite are all black and occur, as in the dunite, in sharp octahedral crystals and irregular grains.

Other constituents.—Serpentine and talc are both largely developed. The alteration of enstatite into talc has been referred to already and this mineral needs no further notice here. Serpentine, as an alternative product of the olivine, presents no phases different from those described under dunite, except its constant accompaniment with anastomosing strings of magnetitic dust. Magnesite is present in varying amount and

is probably a product of olivine weathering caused by the action of surface reagents. Chlorite is present in lamellar aggregates, more or less lath-shaped with curved and imperfectly parallel edges.

c. Epi-amphibole-picrite.

Under this ^{***}title are included a series of somewhat schistose holocrystalline rocks agreeing in mineralogical composition with the hornblende-picrites but differing from them in the origin of the hornblende present. This mineral is not the immediate product of solidification from a molten magma but was formed subsequently during the dynamic metamorphism of the rock.

Epi-amphibole-picrite has been found only at the Hamilton and Track Rock mines, Union County. Here it is associated with the corundum-bearing epi-diorite, and amphibole masses. Its position with reference to these masses is not known. Specimens were found in the miners' dumps which contained only a very few blocks. From the considerable prospecting carried on at both mines, the sparseness of this rock at any of the works indicates that it constitutes only a very small proportion of these basic magnesian bodies. Its presence, nevertheless, in these occurrences is exceedingly suggestive and important, since it helps to unravel some of the problems involved in these corundum-bearing basic magnesian occurrences. Early prospectors for corundum in North Carolina and Georgia sought for the mineral only where there was an outcropping of dunite. As a result, many sources which have since proved productive were overlooked and only by accident discovered. These few finds were distinguished from the dunite outcroppings as "chlorite mines," owing to the greater prominence of the hornblendic masses altering to chlorite. Their lithological relations was not known, and they were considered distinctly *different*. The presence of this rock in these occurrences, however, besides testifying to the origin of the whole mass is evidence that at an earlier period it differed but slightly in mineral composition from those in which dunite outcroppings now appear. It gives the clue, furthermore, to the derivation of the now metamorphosed and altered hornblendic masses associated with it. A further consideration of the important bearing of this rock's presence will be taken up in the summary at the close of this paper.

The epi-amphibole-picrite, or the most basic member of the intrusive masses extending through Brasstown Creek valley, differs but little in

outward appearance from the olivine-gabbros likewise found making up but a small proportion of similar lithological intrusions to the east which play the same geological role as this rock. In the latter, however, grains of feldspar are plainly visible in hand specimens. The epi-amphibole-picrite is a deep dark gray rock with a mottled surface. The texture is distinctly crystalline, but rather finely granular. Under the microscope, olivine is seen to constitute more than half of the rock mass. The remaining constituents are an actinolitic variety of hornblende, chromite, picotite, pleonaste, magnetite, serpentine, chlorite, and magnesite.

The structure is not that of a normal hornblende-picrite but of a rock that has undergone considerable alteration through metamorphism. The olivine is completely fractured; and the actinolite is developed sporadically in small plates between the large fractured olivine individuals, and exclusively in irregular zones through the olivine mass. In such zones, large plates of actinolite border the olivine mass, while within is an intermingling of actinolite and spinel. The mode of the spinel occurrence produces a most curious appearance. It occurs in finely granular patches as minute pale green grains with the actinolite, and also as little colorless film inclusions in the latter. These colorless plates are of such shape and penetrate the mass in such a way as to give the appearance of an aggregation of worms. In the olivine gabbros, the same structure is found and a mechanical separation of the inclusions was effected. The results substantiated the microscopical diagnosis.

Olivine.—Olivine makes up much over half of the rock mass. Like the olivine of the rocks previously described, it is perfectly colorless and transparent. The grains are unusually large but much fractured. The same cataclastic phenomena are developed as were described under the dunites. Spinellid and microscopic doubly refracting glass inclusions likewise occur. The alteration into serpentine is very slight and is represented by anastomosing veins of pale yellowish-green serpentine traversing the olivine individuals. Frequently, however, the narrow fissures are filled with magnetite. The main alteration has been into actinolite, but evidence of the process of this conversion is wanting and the mode of formation is a matter of conjecture.

Spinellids.—The spinellids of this rock differ from those of the dunite and harzburgite in the abundance of large translucent grains and in the introduction of pleonaste which is distinguished by its green color. The color of the spinellids ranges from black, through deep coffee brown, to light brown and green. Some grains have a brown center and a

peripheral yellowish-green zone. In the areas of worm aggregation the spinel grains are all pleonaste. Its occurrence as worm-like inclusions in the actinolite has been referred to previously.

Hornblende.—The hornblende is a colorless actinolite variety which is confined almost exclusively to distinct zones of the olivine mass. In the dunite and harzburgite rocks the amphibole is developed throughout the mass and its pseudomorphism after olivine is plainly referable to weathering brought about by surface agencies. Any intermediate stage of similar alteration in the olivine of this rock is totally wanting and the hornblende presents no evidence of conversion produced purely by weathering. The platy character of the hornblende, the absence of olivine in its zones, and the structural relation of these zones to the olivine mass suggests, on the other hand, that this mineral and its pleonaste associate have been derived from the main mass by metamorphism brought about through dynamic agencies.

The hornblende shows the amphibole rhombic cleavage and high double refraction, and the high extinction angle which characterizes the actinolitic variety. Existing traces of its pseudomorphism are absent, and the mineral presents an entirely fresh and unaltered condition.

The remaining constituents offer no differences in their development and structure from those of the same minerals in the rocks previously described.

d. Anthophyllite-Peridotite.

*Laurelite.*¹³

The association of this rock with dunite and harzburgite was mentioned in the descriptions of the latter and needs no further reference. On account of its external appearance, it is readily distinguished in the

¹³ The term *laurelite* is suggested for this rock since the mineralogical difference between it and the other peridotites is of the same order as that existing between harzburgite and the different peridotites already recognized. The term anthophyllite-peridotite, moreover, is too cumbersome to be satisfactory, and the mass of rock outcropping through several States allows opportunities for pronounced mineralogical variations which would still further burden the terms already adopted. *Laurelite* as suggested would include all those granular to fibrous or radiating masses composed of anthophyllite and olivine.

The type rock from Laurel Creek, Rabun County, Georgia, is a light silvery to greenish-gray granular or radiating fibrous rock, composed of interlocking prisms of anthophyllite through which are disseminated pale green vitreous olivine, and chromite, picotite, and magnetite.

field from the other basic magnesian rocks, since, as far as the writer's acquaintance with these rocks extends, this is the only yellowish-gray fibrous rock found in the corundum-bearing formations of Georgia. Microscopically, it presents a massive yellowish-gray rock, made up of interlocking prisms and radiating fibers of anthophyllite. In thin section, the rock is found to contain a small percentage of olivine, also chromite, picotite, and magnetite; and the alteration minerals, serpentine, talc, chlorite, and magnesite. This rock, therefore, may be designated as an *anthophyllite-peridotite*. On alteration, it passes over into a talcose serpentine.

Dr. C. D. Smith, one of the earlier investigators of the Corundum Belt of North Carolina and Georgia, described a rock occurring with the dunite at Corundum Hill, North Carolina, as being composed almost entirely of anthophyllite and named it "anthophyllite rock."¹⁴ Corundum prospectors over the two states adopted this term and applied it universally to rocks in these formations of similar appearance. In a paper on the economic occurrence of corundum in Georgia, the writer¹⁵ continued the use of this term. Mr. J. V. Lewis in his bulletin on the "Corundum and the Basic Magnesian Rocks of Western North Carolina" calls attention to the use of this name by Dr. Smith and the writer as objectionable, because of an erroneous determination of the fibrous mineral, and adds: "In view of this usage and the extreme scarcity of well determined localities for true orthorhombic amphibole, I had a specimen of the mineral from Corundum Hill analyzed in the laboratory of the Survey by Dr. Charles Baskerville, with the results given below in column I. Talc could be seen in small amounts in the specimen from which the sample was taken. This was carefully excluded from the material analyzed, but the high percentage of water shows that considerable alteration had taken place. *There can be no doubt, however, of the true character of the mineral.* Deducting the water and calculating the percentage of 100, we obtain the results given in column II, *and these figures represent a normal enstatite with a high iron constituent, and near the bronzite variety.* An analysis of another specimen from the same locality by Mr. Frank Julien is given in column III for comparison."¹⁶

¹⁴ Geology of North Carolina, vol. i, 1875, appendix p. 93.

¹⁵ Bull. 2, Geol. Survey, Ga., 1894, p. 82.

¹⁶ Bull. 11, Geol. Survey, N. C., 1896, pp. 26, 27.

	I.	II.	III.	IV.
SiO ₂	51.64	54.95	57.30	57.98
Al ₂ O ₃	0.12	....	Trace	0.63
FeO	9.28	9.89	7.45	10.39
CaO	0.45	....	....	0.20
MgO	31.93	33.97	34.64	28.69
MnO	0.58	....	....	0.31
H ₂ O	5.45	....	1.21	1.67
Loss at 100° .....	....	....	....	1.21
	99.43	98.81	100.60	99.99

In column IV has been added to the analysis quoted by Lewis, an analysis of a mineral from the same locality made and *optically* determined by Penfield to be anthophyllite.¹⁷

A comparison of these analyses is sufficient to show that enstatite cannot be distinguished from anthophyllite by a determination based purely on chemical analysis. The optical and physical properties of both, however, are sufficiently unlike to offer a safe means of distinction, and only through them can an erroneous determination be guarded against. The determination of the Georgia rock is based on these properties.

Anthophyllite.—This predominant constituent occurs in long fibrous aggregates, radial and interlocking, also in masses of thin prismatic individuals. It possesses a high index of refraction and very high double refraction, the colors ranging in the third order of the color scheme given by Lévy and Lacroix. A change in these colors to a light gray seems to be due to an early stage in alteration. A traverse parting which occurs in the prismatic plates and sections at right angles to these plates, shows acute amphibole rhombs. The extinction lies parallel to the fibers and prismatic plates and diagonal to the rhombic cleavage. Alteration into talc has been more or less progressive in different specimens. The frayed ends of the mass of thin prismatic individuals show the advance of talc alteration.

The specimens of anthophyllite-peridotite from Soquee, Laurel County, are more altered than those from Laurel Creek, Rabun County, and show an almost complete transition to a talcose serpentine—the serpentine being derived from the original olivine content. There also occur in the specimens from Soquee, a few sporadic tabular crystals of colorless enstatite. The enstatite is distinguished by an extinction parallel to the

¹⁷ Amer. Jour. Sci., vol. xli, p. 394, 1890.

pinacoidal and diagonal to the prismatic cleavages, rectangular rhombic cleavage on basal sections, a high index of refraction, and low interference colors.

e. Amphibolite.

In a petrographical sense, the most important development of this non-feldspathic type is at the Miller asbestos property, about two miles north of Barton, Rabun County. The outcrop here, although mainly dunite, has apparently only amphibolite as an associate. Under the term amphibolite, are included all rocks composed essentially of actinolite. The Miller amphibolite is not completely altered to actinolite, as are all the other specimens, hence its petrographical interest. The intense dynamic forces which gave schistosity and fine granulitic texture to the dunite, left similar evidences of squeezing on its pyroxenite neighbor, and more—it *partially* paramorphosed the pyroxenite into actinolite. The effects of the dynamic forces which produced this paramorphism is most pronounced when viewed in thin section. Peripheral granulation always accompanies the presence of the larger individuals in contact with each other, and, what is most common, deep borders of finely granular material separate the grains which furnished it by grinding on one another. No matter how finely they have been crushed, the particles fit into their neighbors closely, and no product of hydration is present. The alteration of the diallage is due plainly to dynamic action. The alteration begins at the borders of the grains and works toward the center. Cross-sections of the basal plane of diallage show the change from the rectangular to the acute rhombic angle as the paramorphism advances.

The amphibolite from the Miller property is a hard, compact, fine-grained rock of a dark gray color and a slaty cleavage. Its mineral composition is actinolite, diallage, chromite, picotite, and magnetite in black octahedral and irregular grains.

The average amphibolite differs from the above in the total absence of diallage. In other words, they represent a complete paramorphism of the parent mineral.

f. Chlorite-Amphibole Schists.

These schists represent the partial alteration of the epi-amphibolite rocks and characterize the surface of those basic magnesian intrusives in which pyroxene facies have been differentiated. This is especially true

of the Brasstown Creek region where their boulders thickly strew the disintegrated masses. Dark green in color, they possess a schistose structure and fine granular texture. As the rocks become more completely chloritized the schistosity increases and the texture becomes platy. Under the microscope, they show a granular mass of characteristic actinolite more or less altered to chlorite. The optical properties of this chlorite are those of clinocllore.

g. Serpentine and Steatitic Masses.

Serpentine masses only occur in those localities where dunite or harzburgite is prominently developed, and its derivation may be referred directly to masses rich in olivine. Evidence of this is conclusive since the alteration and hydration are incomplete, and serpentine masses uncharacterized by minerals of which the rock was originally composed are unknown in the Corundum Belt. Thus, as may be inferred, the line of demarkation is not sharp between olivine masses and their alteration product, serpentine.

At Laurel Creek, where the serpentine is best observed, the megascopical appearance is very similar to that of dunite. Specimens, which show in thin sections almost complete conversion of the olivine, possess a darker color, and the tremolite is more talcose. Under the microscope, the characteristic mesh-structure due to the separation of magnetite along the original cracks of the olivine defines the former structure of the olivine. Even in the most altered specimens, also, remnant grains of incompletely serpentinized individuals occur sporadically distributed through the irregular serpentine network. The serpentine mass contains, besides the fibrous serpentine and magnetite, considerable magnesite and talc.

The steatitic masses are confined to the laurelite localities, and are the alteration products of this rock. Like the serpentine masses, the alteration and hydration are not so complete but that olivine grains and fibrous anthophyllite remain to identify the original rock mass. Megascopically, the fibrous character of the original rock has more or less disappeared beneath the aggregated scales of talc. Under the microscope sections of this rock show patches of talc scales and fibers of unaltered anthophyllite irregularly mingled with the mesh-structure of serpentinized olivine. Through the mass are scattered black grains of spinellids.

2. THE FELDSPATHIC OR GABBRO TYPE.

a. Epi-diorite.

This facies of the gabbro type is very prominently developed in the corundum-bearing rocks of Towns and Union counties, and always forms a large proportion of those basic magnesian intrusions of which it is a member. It is a medium grained schistose rock, composed essentially of an actinolitic amphibole and an anorthite plagioclase, and has for accessories chromite, picotite, magnetite, and corundum, with the latter's alteration mineral, margarite. When the proportional percentage of the two essential constituents is about equal, the rock has a mottled, deep greenish-gray color and vitreous lustre. The two essential constituents, however, continually alternate in their prominence throughout the rock mass, thus forming a series whose limiting members are almost devoid of the mineral composing the complementary member. Hence, rock masses of this character show facies consisting either almost wholly of anorthite, or almost entirely of actinolite, which are united by many intermediate gradations.

Since the mineralogical composition and structure of these rocks plainly show that their original character has been greatly changed through metamorphism, the term *epi-diorite* is here employed to embrace all rocks answering to the above description found in the corundum-bearing basic magnesian formations.

In the Georgia localities, epi-diorite is associated with its alteration masses, amphibole-chlorite and talc-chlorite schist, and also with dunite, epi-amphibole picrite, and olivine-gabbro. The former characterize the disintegrated outcrops, while the latter are very poorly represented. The main line of outcrops in which these basic magnesian rocks are represented, extends for five and a half miles from Track Rock, Union County, in a northeasterly course through Brasstown Creek valley to the Hamilton mining locality. The limits of these intrusions in Track Rock and Hamilton corundum mines, show the largest surface development and offer the best opportunity for petrographical study, because of the mining operations carried on in both localities. Here the effects of excessive dynamic action are apparent both in the gneissoid character of the rocks and the schistose structure of the mass, the strike of its schistosity conforming with that of the country rock. A further effect, also, is witnessed in the metamorphosed condition of the mineral constituents. In spite, however, of this dynamic metamorphism, conclusive

evidence of the original identity of the most altered masses, *e. g.*, epidiorite and its alteration masses is probably to be found in the less metamorphosed masses forming this long line of outcrops. The connecting link is the olivine-gabbro, which outcrops in a small mass about a mile north of Young Harris. It is composed essentially of pyroxene, olivine, and feldspar, the former partially altered to actinolite. The lithological transition is therefore complete. The three members, epi-amphibole-picrite, epi-amphibolite, and epi-diorite, now represented in these basic intrusions, were derived directly through dynamic metamorphism from picrite, pyroxenite, and gabbro respectively, by the alteration of the pyroxene constituent.

That this alteration of the pyroxene into actinolite was brought about by dynamic agencies is plainly evident not only in the epi-amphibole-picrite and epi-amphibolite but also in the epi-diorite. The evidence of this is apparent in the remarkable freshness of the feldspathic constituent of the epi-diorite, for, had the rock mass been sufficiently affected by the surface agencies of weathering to produce perfect pseudomorphs of actinolite, the plagioclase would certainly show some alteration.

Lewis describes¹⁸ similar masses in the Buck Creek and Shooting Creek corundum mining localities of North Carolina. He represents the former locality as "the largest compact mass of peridotite in the State, and in fact, the largest yet observed in the State, and in fact, the largest yet observed in the Appalachian belt." This description is accompanied by a map of the Buck Creek corundum mine, showing the surface distribution of the following types: dunite, "forellenstein," amphibole-picrite, and amphibolite. The two latter are described in this paper under the terms epi-amphibole-picrite, and epi-diorite respectively. In this intrusive mass, therefore, even the unaltered olivine rock, dunite, is present and the chain of evidence establishing the original mineral composition of the metamorphic members is complete.

Plagioclase.—The most striking feature of the epi-diorites, is the appearance of the plagioclase. When this constituent is greatly in excess of the amphibole, it presents, microscopically, a finely granulated or sugary texture. Peripheral granulation which naturally would be expected to accompany this texture is observed only occasionally in this section. The small grains fit into each other closely and are beautifully twinned after the three laws, carlsbad, albite, and pericline. Inclusions

¹⁸ Bull. 11, Geol. Survey, N. C., 1896, p. 36.

of microlitic needles and grains of actinolite are abundant, also small eyes of feldspar. There is not the least trace of alteration and from its extreme freshness the mineral suggests its formation through recrystallization. The extinction angle, measured along twinning lamellæ, is very high, and places it in the anorthite series.

Amphibole.—The amphibole is colorless to light yellowish green. A faint pleochroism in pale yellowish tones $c = b > a$ is occasionally seen. The optical orientation is that for the actinolite variety $b = b, c : c$ as high as 21° .

Like the feldspar it is unaltered and includes small feldspathic lenses and minute grains of corundum.

Accessory Constituents.—Only a few accessory minerals occur. Corundum, the most prominent, is sometimes developed in large grains, often an inch or more in dimension. The color varies in light blue and pink tones, megascopically, but disappears in thin sections. It is readily distinguished under the microscope by its parallel parting, low interference colors, and its high relief borders and shagreened surface.

The spinellids, chromite, picotite, and magnetite are always present. All the large grains have a coffee brown color, likewise the minute grains when not black.

Margarite occurs in weathered specimens but is not seen in the fresh rock. It occurs as a pearly grayish-white mantle about the grains of corundum and is obviously a direct alteration product.

b. Smaragdite-epi-diorite.

This variety of epi-diorite is known to occur in Georgia only at the Bell Creek corundum mine, four miles north of Hiawassee, Towns County. Only dump specimens were to be found, since the excavation from which the rock was thrown out has been filled in for some years. The outcropping at Bell Creek of the basic magnesian rocks is very small and consists of talcose and chloritic hornblende schists. Although all the rocks to be seen *in situ* are much weathered, the mass distinctly resembles that at the Track Rock and Hamilton mine localities, and is probably of the same lithological character. When the amphibole makes up a large percentage of the rock, this variety of epi-diorite possesses a most attractive grass green color and vitreous lustre, the effect of which is increased by the abundant distribution of small grains of bright blue sapphire. Its texture and structure corresponds precisely with the epi-diorite just described. It differs from these epi-diorites only in the

chemical composition of the actinolite, the additional presence of chromium in the amphibole producing the variety of actinolite known as *smaragdite*.

Amphibole.—With the exception of color, the amphibole of this rock mass shows the same optical and physical features as in the epi-diorite amphibole. The color, according to *Raddes International Farben Scala*, is “grasgrün K. M. 15, Cartoon 5.”

Dr. Genth had analysed the amphibole of a corresponding rock from Cullakama mine, Clay County, North Carolina, and considered the amphibole “Smaragdite (?) Kokschwarowite.”¹⁹ Dana from the same analysis refers it to the species edenite.²⁰ Mr. J. Volney Lewis, the latest to publish on this mineral, still doubts²¹ the accuracy of the term Smaragdite, and compares a recent analysis of material from same locality with that used by Dr. Genth. Both analyses follow:

Analyses of Aluminous Hornblende from Buck Creek, Clay County.

	Lewis.	Genth.
SiO ₂	44.38	45.14
Al ₂ O ₃	17.32	17.59
Cr ₂ O ₃	0.38	0.79
FeO	3.83	3.45
NiO .....	....	0.21
MgO	15.48	16.69
MnO	0.90	....
CaO	11.51	12.51
NaO	1.24	2.25
K ₂ O	0.38	0.36
H ₂ O	4.63	1.34
	100.03	100.33
Sp. Gr.	3.075	3.100

Both analyses err for the same reason—the material analyzed was not pure. The figures of these analyses do not represent a stoichiometrical compound as may be seen readily by reducing them to an empirical formula. The rich aluminous content of both analyses, which has caused the confusion, is undoubtedly due to microscope inclusions of corundum from which the amphibole perhaps cannot be isolated. Dr.

¹⁹ Bull. 74, U. S. G. S., 1891, p. 45.

²⁰ Dana's System of Mineralogy. Sixth edition, p. 395.

²¹ Bull. 11, Geol. Survey, N. C., 1896, p. 28.

Rosenbusch encountered the same difficulty in an unpublished analysis of a corundum smaragdite rock made in his laboratory, and on his authority the amphibole of this epi-diorite is termed smaragdite.

c. Garnet-epi-diorite.

This variety²² of epi-diorite was collected from surface boulders near Villa Rica, Douglas County. It differs from the usual epi-diorite in its massive character, the absence of corundum, and the presence of garnet. It is the only occurrence of the kind observed among the basic magnesian rocks of the Georgia Corundum Belt.

The rock is dark green and massive. Large pseudo-phenocrysts of dark green actinolite occur in a fine-grained background through which are also scattered irregular patches of massive pink and white garnet. The actinolite phenocrysts have the dimensions of an inch or more, while the garnet areas are several inches in diameter. Anorthite plagioclase and actinolite make up about equal proportions of the ground mass. The remaining constituents are pleonaste and magnetite.

Garnet.—When apparently free from inclusions, the garnet has a pink outer zone and white interior. A pseudo-cleavage occurs on a freshly fractured face which tends to mislead in a megascopical determination. In thin sections, the garnet areas are found to be thickly impregnated with inclusions which consist mainly of pleonaste and actinolite. Feldspar inclusions are also present. The pleonastes are by far the most numerous and occur in green grains of variable size and in minute colorless flakes.

d. Olivine-gabbro.

Wherever olivine-gabbro is known to form a part of the basic magnesian rocks in the Georgia corundum deposits, it is always in association with epi-diorite and amphibole masses. From the different localities where it was found, specimens of the following facies were collected: dunite, epi-amphibole-pierite, olivine-gabbro, epi-diorite, and amphibole masses. Of the five facies, only three have suffered dynamo-metamorphism, the dunite and olivine-gabbro remaining mineralogically unchanged. That the metamorphism of epi-amphibole-pierite, epi-diorite, and the amphibole masses was due to the uralitization of the pyroxene constituent has been especially noted in their description. In all these rocks, the micro-

²² Collected by S. W. McCallie, Geol. Survey, Ga.

scope apparently offers no evidence of the change of any other mineral by dynamo-metamorphic conversion into another species. While all are noticeably effected by dynamic agencies, no mineralogical change in the rock mass resulted. From the data, therefore, which the petrographical study of these rocks has developed, the following table showing the differentiation of the solidified magma and its present alteration through dynamo-metamorphic uralitization of the pyroxene seems justified.

Original	Minerals	Metamorphic
Magnesian type	{ Dunite =	Olivine chromite
	{ (Picrite) =	Diallage olivine chromite = Epi-amphibole-picrite
	{ Diallagite =	Diallage chromite = Amphibole masses
	{ (Trotolite) =	Feldspar olivine chromite
Gabbro type	{ Olivine-gabbro	Feldspar diallage olivine chromite = (Epi-olivine-diorite)
	{ (Gabbro) =	Feldspar diallage chromite = Epi-diorite

The members in brackets () have not been found, but probably occur.

Olivine-gabbros when poor in feldspar present little difference megascopically from epi-amphibole-picrite. They possess the same fine granular texture, dark gray color, and massive structure. The feldspar of the olivine-gabbros, however, is present usually in such large proportion compared with the development of the ferro-magnesian constituents that the two types are readily distinguished from each other.

As with the epi-diorites, the percentage of feldspar varies so widely that a gradation series of olivine-gabbros occurs. In thin sections, the olivine and pyroxenes are seen to vary likewise in predominance.

The mineral composition of the olivine-gabbros is very similar. All contain anorthite, plagioclase, olivine, diallage, enstatite, chromite, picotite, magnetite, and serpentine, and one specimen, that from Hog Creek, Towns County, contains brown hornblende.

Ferro-magnesian constituents.—Diallage appears to be the most commonly developed pyroxene in these rocks. In polarized light it is seen to be intergrown frequently with very thin lamellae of enstatite. It is also partially surrounded by a parallel growth of the same mineral. In the Hog Creek rock tabular microscopic interpositions producing the so-called

schillerization characterize certain sections of the mineral. Brown hornblende is developed in the Hog Creek rock quite extensively. Sometimes it partially surrounds the pyroxene and again it is enclosed by the pyroxene. Hence it apparently occurs in two generations; in the first case, probably older than pyroxene, in the latter younger.

Spinel inclusions.—Spinel grains are abundantly developed in the olivine-gabbros, and as in the case of the other feldspathic types, when not microscopic in size, are translucent and of a coffee-brown color. The most interesting occurrence of the spinel, however, in these rocks is when it occurs as colorless flakes through the pyroxene. These flakes resemble worms in closely parallel and radiating directions. Between crossed nicols the color of such intercalated grains is most variegated and fanciful. The isotropic character of such inclusions is, nevertheless, immediately betrayed by accompanying extinction with the host.

Equally interesting are the crystal inclusions of the same mineral in the feldspar. These occur in octahedral but generally elongated microscopic colorless inclusions, the longer direction corresponding to the twinning lamellae of the anorthite. These crystals, and occasionally a worm, are not so numerous developed in the feldspar as the worms in most sections of the pyroxene. They differ also in showing a much higher relief, thus marking the difference in refraction of the hosts.

These spinel inclusions were isolated with considerable difficulty. It was discovered after various trials that the worms were so filmy that they hung in suspension several days, or long after the chemical products of decomposition had been precipitated.

ORIGIN OF THE GEORGIA CORUNDUM-BEARING BASIC MAGNESIAN ROCKS.

In order to determine the origin of rock masses in ancient crystalline regions, the geologist, failing to find conclusive evidence in the field relations, must turn his attention to their chemical and microscopical features. In undisturbed crystalline regions, where no great orographic movements have effaced original features, and decomposition of the rock masses is not extensive, the two great classes of rocks, igneous and sedimentary, retain unmistakable signs of their origin, and the field relations offer satisfactory evidence for their separation. When, however, great metamorphosing influences have been exerted to such an extent that field guides are effectually obliterated, then chemical or microscopical features become the final resort, and even these may perhaps fail in cases of extreme metamorphism.

The Corundum Belt of Georgia presents a field in which intense dyn-

amic action has so squeezed and sheered the rock masses that those of igneous origin have been foliated and banded and probable clastics have become thoroughly crystalline. To what extent dynamic action has concealed the original nature of these rock masses has never been fully investigated. The tendency, however, to consider the whole area of igneous origin has been checked by the present chemical study of the gneisses occurring along the Appalachian Crystalline Area. In the case of the basic magnesian rocks which are considered by most geologists to be igneous intrusions, field evidence of their origin, if not entirely wanting, is very obscure. The existence of distinct contact zones has been observed neither in Georgia nor in North Carolina.²³ This failure may be due to concealment by subaerial decay and soil cultivation which so frequently renders close observation impossible. Nevertheless their absence is not surprising in such a highly crystallized and metamorphosed region since the intense dynamic changes which have affected the entire Corundum Belt would possibly have totally obliterated them. Not infrequently, mica-schist is developed in the adjoining gneiss and invariably the basic magnesian mass has an external zone of talcose schist. These, however, are undoubtedly products of dynamic metamorphism. Julien²⁴ alone, of the geologists who have studied these basic magnesian rocks, considered them of sedimentary origin and all derived from dunite. He argued that their lamination indicates the bedding planes of a mechanical sediment and offered as further field evidence that he found in certain instances these rocks interbedded with hornblende gneiss, but never hornblende gneiss enveloped by them. These arguments, however, are valueless, since it is well known that the same conditions could exist in a metamorphosed area if the basic rocks were igneous. Julien further supported his opinion by microscopical features of the dunite. He claimed, first, that sections sawed transverse to lamination showed alternating laminae of coarse and fine irregular grains; second, that chromite was dispersed in the rock as in siliceous sands of the sea coast and were also concentrated in laminae alternating with olivine grains. In all slides examined by the writer, the first observation seems to be a misinterpretation of fact, the second has not been found. The apparent alternating laminae of small and large olivine grains is more strongly suggestive of cataclastic action than water sorting. Neither the small nor large grains of olivine show even the partially rounded appearance which

²³ Bull. 11, Geol. Survey, N. C., p. 16.

²⁴ Julien, A. A., Proc. Nat. Hist. Soc. Boston, vol. xxii, 1882, pp. 141-149.

one would expect in a water-worn aggregate. On the contrary, the small grains are sharply angular and fit into one another like a mosaic, while the large grains likewise show phenomena of cataclastic action. Indeed, the whole microscopical structure of the dunite is that of an igneous rock with the secondary structure due to pressing and shearing. Wadsworth after studying dunites from North Carolina arrived at the same conclusion, and his argument seems quite conclusive.²⁵

Rocks crystallized from a molten magma have been found to obey certain chemical laws in their composition which can only vary within definite limits. This fact affords a quite definite guide in the recognition of the original character of rocks. If a rock be sedimentary, no matter how highly metamorphosed, the purely mechanical processes of its formation will give an indefinite character to its bulk composition. These facts were amply illustrated by Rosenbusch²⁶ who showed through a large series of analyses the marked contrast in bulk composition between igneous rocks and simulating crystalline rocks whose sedimentary character has been destroyed by metamorphism.

If the Georgia and North Carolina dunites are of sedimentary origin, it is then not unfair to suppose that their chemical bulk composition would show some noticeable variations. A comparison of all the analyses of dunite which the writer has been able to collect bear the most striking resemblance to each other. Lest this similarity be a matter of accident, a comparison of the same was made with analyses of typical dunite from New Zealand, whose igneous character is unquestioned. The results remain the same, as may be seen by comparing the analyses tabulated below.

	SiO ₂	MgO	FeO	Al ₂ O ₃	Na ₂ O	NiO	MnO	CaO	Chromite	C ₂ O ₃	Igation	H ₂ O	Total
Laurel Creek, Ga.....	42.71	41.18	6.83	0.70	....	0.32	0.09	....	..	....	8.38	....	100.21
Corundum Hill, N. C.	40.11	48.58	7.29	....	....	....	....	....	0.56	0.18	..	2.74	100.34
" " "	41.58	49.28	7.49	0.14	....	0.34	....	0.11	..	....	..	1.72	100.66
Dun Mt., N. Zealand.	42.80	47.38	9.40	....	trace	....	....	....	..	....	..	0.57	100.15
" " "	42.69	46.90	10.99	....	....	trace	....	....	..	....	..	0.49	100.17

1. Bull. 2, Geol. Survey, Ga., p. 81.

2. Bull. 42, U. S. G. S., p. 55.

3. Zirkel, Lehrbuch d. Petrographie, vol. iii, p. 121.

²⁵ Mem. Mus. Comp. Zool., vol. xi, part I, 1884, p. 118.

²⁶ Zur Auffassung der chemischen Natur des Grundgebirges. Tsch. Min. u. Pet. Mitth., vol. xii, 1891, pp. 49-61.

From the application of microscopical and chemical criteria, it seems, therefore, that we may safely assume an igneous origin for the Georgia dunite.

1. Because the structure of the dunite is only that which an igneous rock would present.

2. Because the definiteness in character of their bulk composition points likewise to an origin from a molten magma.

Since dunite or a derivative is always found as an integral part of all the corundum-bearing magnesian masses, the same inference must be drawn for all their members.

SUMMARY.

In the preceding pages special emphasis has been placed on the following facts and conclusions:

1. The basic magnesian rocks associated with the corundum deposits of Georgia are confined to a narrow crystalline zone lying between two strips of semi-metamorphic sediments, the Ocoee series.

2. This crystalline zone, the so-called "Corundum Belt" is largely composed of gneisses and the basic magnesian rocks considered in the preceding discussion.

3. The structural features of this "Corundum Belt" show orographic movements in which the force acted from the southeast and was probably of long duration.

4. Its gneisses probably represent early Paleozoic sediments.

5. Field evidence concerning the origin of the basic magnesian rocks associated with the corundum deposits is apparently wanting, but their chemical and microscopical features show that they are the products of a cooling magma.

6. Magmatic differentiation produced on consolidation two rock types: first, a non-feldspathic or magnesian type, and second, a feldspathic or gabbro type.

7. All well exposed outcrops are found to contain the first type, and some, both types.

8. Dynamo-metamorphism has more or less modified the original mineral composition of these types, and their identity is further obscured by surface decomposition.

9. All the dynamo-metamorphic rock masses have been derived through the uralitization of pyroxene, the nature of the other mineral constituents remaining unchanged.

LIFE.

Francis Plaisted King was born in Portland, Maine, February 14, 1867. His early education was received in the public schools of his native city. In the fall of 1886, he entered Colby University, and in 1890 received from this institution the degree of Bachelor of Arts. During the last two years of his academic course, he entered into special work with Dr. W. S. Bayley, Colby's Professor of Geology and Mineralogy, and in the field seasons of 1889, 1890, and 1891 acted as field assistant in the Lake Superior Division of the U. S. Geological Survey. Johns Hopkins University was entered in 1890 where he remained three years, devoting his time to the study of geology under Professors George H. Williams and W. B. Clark. During this period, he received the appointment of University Scholar, and Fellow in Geology. He became Assistant State Geologist of Georgia, July 1, 1893. Resigning this position April 1, 1896, he entered Heidelberg University and studied in the laboratories of Professor H. Rosenbusch and V. Goldschmidt during the summer semester of that year. In the fall of the same year he returned to the Johns Hopkins University as Fellow by Courtesy and continued his work in geology under Professor W. B. Clark and Dr. E. B. Mathews.

